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Heat Stress Field Study

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Every summer the Marine Corps sends several thousand reservists to its Air Ground Combat Center, Twenty-nine Palms, CA, for 2 weeks of training. This article presents results from three separate field exercises in which data were collected on environmental conditions. It also discusses epidemiology of the heat-related casualty (HRC) and non-HRC populations and includes a compilation of anecdotal data from the field hospital staffs. The purposes of these investigations were to identify high-risk individuals and the activities that may contribute to increased casualty rates, to suggest procedures for prevention, and to increase the efficiency of remedial treatment with the ultimate goal of eliminating heat-related casualties.

Procedure and Methods

The senior author attended three major exercises and collected epidemiological information on two combined arms exercises (CAX) through the summers of 1979 and 1982. During those exercises, interviews were conducted with about 10 percent (263) of those personnel who never reported themselves as heat casualties (controls) during desert exercises. An HRC is defined as a person who reported to or was referred to either a battalion aid station or the field hospital with symptoms of high body temperature, nausea, cramps, heat exhaustion, or heat stroke. An epidemiological data sheet was completed for each casualty. Other cases of undocumented heat-related illnesses in the field, which were treated successfully by the unit corpsmen or by the patient's friends, were not included in this survey.

Environmental temperature and relative humidity were measured with a Thunder Scientific Corporation digital humidity and temperature measurement system (model HS-1CHDT-2A). A black-globe temperature was determined from a thermistor inserted

TABLE 1: Heat-Stress Conditions

Condition	WBGT (°F)	Limitations
I	≥80	Heavy exercise should be performed with caution and under close supervision.
II	≥85	Strenuous exercise should be suspended for unacclimated individuals for 2-3 weeks. Outdoor classes should be avoided.
III	≥88	All physical training should be halted for unacclimatized troops and for those who have not lived and worked in the area for at least 2 weeks. Acclimatized troops may carry on limited activity not to exceed 6 hr/day.
IV	≥90	All strenuous activity should be halted for all troops.

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TABLE 2. Subjects by Area of Residence (Percent of Total)

Area	Controls	HRC 1979	HRC 1982	Combined HRC 1979 & 1982
Southwest, CA, HI	31	21	29	22
Northwest	13	4	0	3
Rocky Mts., Central Plains	6	0	0	0
Deep South	21	43	47	44
North Central	3	9	12	9
Northeast	21	17	6	16
Unknown	5	6	6	6

TABLE 3. Subjects by Military Grade (Percent of Total)

Rate/Rank	Controls	HRC 1979	HRC 1982	Combined HRC 1979 & 1982
PFC	10	14	29	16
LCPL	29	33	12	31
CPL	16	20	23	20
SGT	10	13	18	14
SSGT	7	7	0	6
GSGT	5	3	0	3
Officer	21	4	6	4
Unknown	2	6	12	6

TABLE 4. Hours of Sleep (Percent of Total)

Hours of Sleep*	Controls	HRC 1979	HRC 1982	Combined HRC 1979 & 1982
<2	0	10	6	10
2-3	6	28	41	30
4-5	49	35	35	35
6-7	41	20	18	19
>8	0	0	0	0
Unknown	4	7	0	6

*Amount of sleep the night before being sampled as a control or HRC.

into the center of a matte-black copper sphere 15 cm in diameter. Both natural and psychrometric wet-bulb temperatures were recorded. Cloud cover was estimated using a 0.0 to 1.0 relative scale for percent of sky coverage. The environmental conditions were recorded hourly between 0700 and 1700 at Twentynine Palms Marine Base Dispensary, at Camp Wilson's field hospital, and at various sites on the ranges.

The anecdotal medical information was collected from interviews with the medical staffs of the field hospital, battalion aid stations, corpsmen in the field, and from personal observation.

Results and Discussion

Environmental Conditions. The daytime temperatures were higher at the Camp Wilson field hospital area then at Twentynine Palms Dispensary station by about 1°to 3°C, and relative humidity was greater at Twentynine Palms by about 5 to 15 percentage units. The fluctuations and elevated relative humidity at Twentynine Palms were probably the result of increased vegetation and local sprinkling.

At Twentynine Palms the heat-stress conditions were divided into four categories based on the wet-bulb globe temperature (WBGT) index. Condition I is the least severe and condition IV the most severe. Table 1 shows the recommended activity levels at each heat-stress condition and corresponding WBGT. Since few of the reservists are heat-acclimatized, conditions II and III should be the limits of activity for these troops.

Condition IV is most likely to occur between 1200 and 1500 hours. About 10 percent of the time it can occur as early as 1100 and as late as 1600 hours during June, July, and August. The rate of temperature increase in the morning is almost exponential between 0900 and 1100, and declines rather slowly between 1500 and 1700 hours. The Corps exercises near the end of the summer (August to mid-September) are more likely to encounter high humidity, slightly cooler days,

more cloud cover, and an occasional wind and rainstorm at night. Those during June and July are the most difficult for the unacclimatized reservists, and are the exercises most likely to increase the number of heat casualties.

The 1979 exercise period (14-28 July) was considerably hotter and drier than the 1982 exercise period (20 Aug-1 Sept). Although the casualty rate was about eight times higher than in 1982, considerations other than environmental temperature probably contributed to the reduced HRC rate in 1982.

Epidemiology. After reviewing the results of the surveys for the control population of each exercise, which showed that the differences were minimal, the data for the two control populations were combined. The data for both the control and HRC groups are presented as percentages of the total sample. Data from the HRC groups for the 1979 and 1982 exercises were also combined.

Table 2 presents data from the controls and casualties divided according to the section of the country in which the reservists lived. The hypothesis was that people from the cooler areas would be at a greater risk, and that those from the South and Southwest would be partially heat-acclimatized and thus at a lower risk. This hypothesis was not confirmed (Table 2). Personnel from the Deep South and north-central sections of the United States were at two and three times greater risk, respectively, than the controls. Although personnel from the Southwest, Hawaii, and the Pacific States composed about 44 percent of the population, only about 25 percent of the heat casualties were from these areas. Interviews with many of the casualties from the Deep South revealed that most lived and worked in air-conditioned houses and offices.

Table 3 presents the data according to rate or rank. Neither rate nor rank appeared to increase the risks above that which would be expected according to the general population. Since

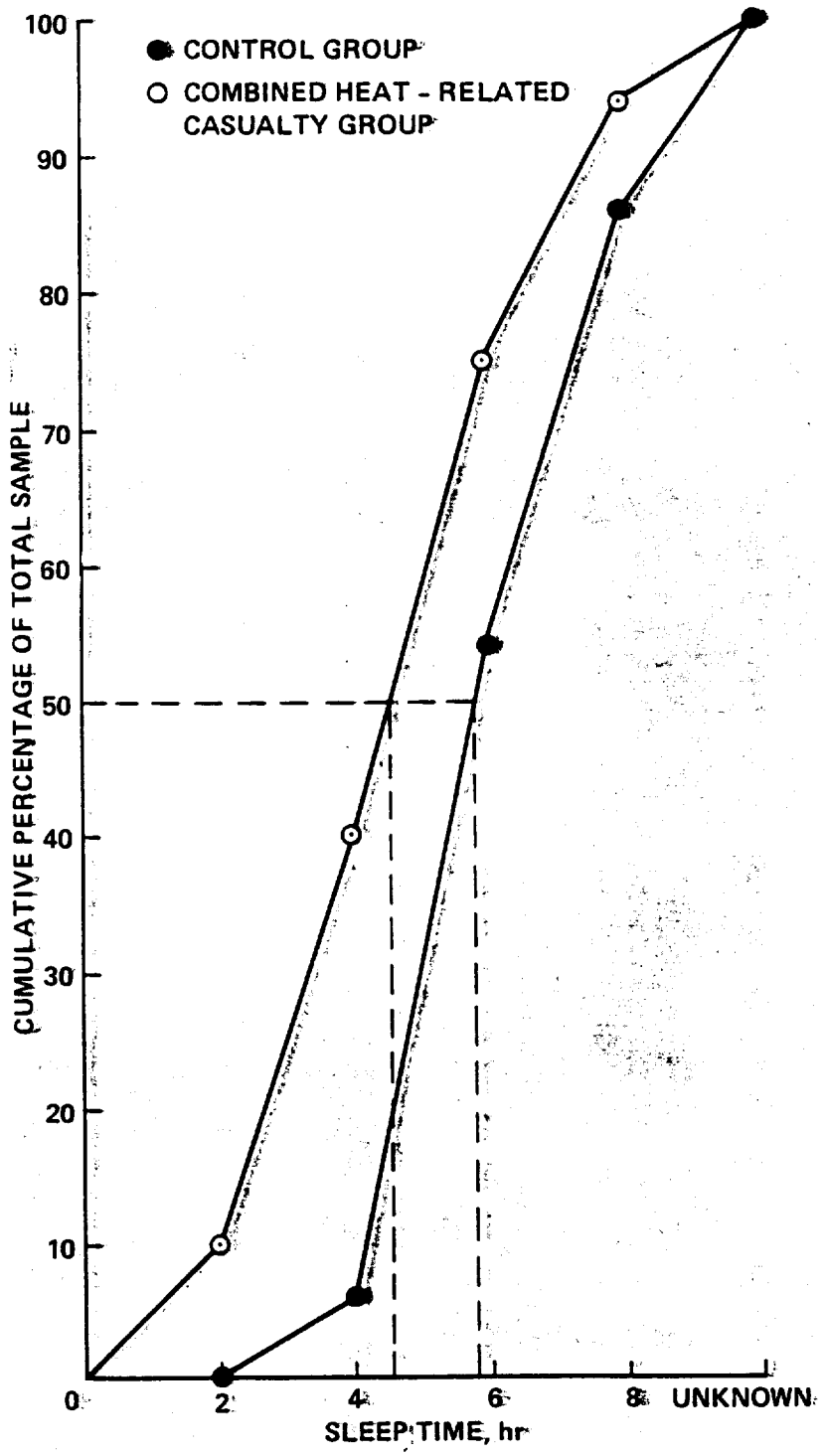

FIGURE 1. Average sleep time during the exercise in the control and HRC groups.

TABLE 5. Subjects by Race (Percent of Total)

Race	Controls	HRC 1979	HRC 1982	Combined HRC 1979 & 1982
Black	10	26	29	26
Caucasian	75	71	71	71
Hispanic/Am. Indian	2	0	0	0
Oriental	5	1	0	1
Unknown	8	2	0	2

TABLE 6. Subjects by Sex (Percent of Total)

Sex	Controls	HRC 1979	HRC 1982	Combined HRC 1979 & 1982
Male	95	95	88	94
Female	5	5	12	6
Unknown	0	0	0	0

TABLE 7. Beer Consumption (Percent of Total)

Can of Beer, 12 oz.	Controls	HRC 1979	HRC 1982	Combined HRC 1979 & 1982
None	36	58	65	59
<2	13	20	12	19
2-4	28	10	23	11
>5	23	5	0	5
Unknown	0	7	0	6

TABLE 8. Salt Use (Percent of Total)

Added Salt*	Controls	HRC 1979	HRC 1982	Combined HRC 1979 & 1982
Yes	39	63	47	61
No	59	30	53	33
Unknown	2	7	0	6

*Salt added to food other than field rations.

about 29 percent of the sampled control population were lance corporals (LCPL's) one would expect a similar percentage of the pooled heat casualties to be LCPL's, which was observed.

Since fatigue contributes to the incidence of heat exhaustion and heat stroke, the hours of sleep the patients had before becoming heat casualties were determined. Table 4 lists the reported hours of sleep each person had the night before becoming a heat casualty. None of the controls had fewer than 2 hours of sleep, whereas about 10 percent of the casualties had fewer than 2 hours. Fifty percent of the controls had about 5.8 hours of sleep, and 50 percent of the heat-related casualties (HRC) had about 4.5 hours (Figure 1). About 54 percent of the controls had 6 or fewer hours of sleep, whereas 75 percent of the casualties had 6 hours or less. It is interesting that 41 percent of the controls slept between 6 and 8 hours, and that only 19 percent of the HRC group had that much sleep.

Table 5 tabulates the data by racial type: Black, Oriental, Hispanic and American Indian, Caucasian, and unknown. Although Blacks comprised about 10 percent of the controls, they comprised about 26 percent of the HRC group.

There appeared to be no difference between the HRC and control groups with respect to sex (Table 6). The larger percentage of female HRC's during 1982 may be due more to the small size of the HRC group rather than an actual increase in the risks to females. Nothing in the field indicates that females are at a greater risk of becoming heat-related casualties. Compared with larger people, small women, as well as small men, may be under greater work stress when performing heavy manual labor. The female casualties in 1982 occurred while they were standing in formation on hot metal slats, which raises questions about the quality of their supervision. The 1979 female HRC group engaged in a wide range of noncombat tasks, i.e., cleaning trucks, riding in

jeeps, attending lectures in the sun, and splicing wire.

Beer was available at night, and there was some concern that alcoholic intake contributed to the increase in the heat casualty rate. Table 7 lists the consumption of beer (12-oz cans) by the two groups. Seventy-five percent of the control population had fewer than 3.9 cans, and 75 percent of the HRC combined group had fewer than 1.7 cans (Figure 2). At the 50 percent level, the control group and the HRC combined group consumed 2.1 and 0.0 cans, respectively. The implication of these data is that a few cans of beer at night might be beneficial. Although data exist that show a dehydrating effect of alcohol on fully hydrated individuals, no data are available that indicate if alcohol has a potential rehydrating effect on slightly or moderately dehydrated people. Possibly, with dehydrated individuals, American beer with its low alcoholic content may have a positive rehydrating effect. (Similar observations of beer consumption after work in hot environments have been reported in South African mine workers and in iron and steel mills in the northeastern United States.) The effect of salt added to beer consumed by mildly dehydrated individuals has not been fully investigated; it may prove to be beneficial, particularly if proper meals, especially the evening meals, are not eaten regularly.

When asked if their food, other than field rations, was salted, the controls reported affirmatively in 39 percent of the cases. By comparison, 61 percent of the HRC combined group reported adding additional salt to their food. Table 8 lists the percentages of those who salted their food when not eating field rations. Since members of the HRC groups appeared to have salted their food more frequently than the control population, the next question should ascertain the amount of water consumed. If the HRC group was consuming more salt, they should have been consuming more water.

Table 9 categorizes the volume of water (number of 1-liter canteens) consumed other than that taken at

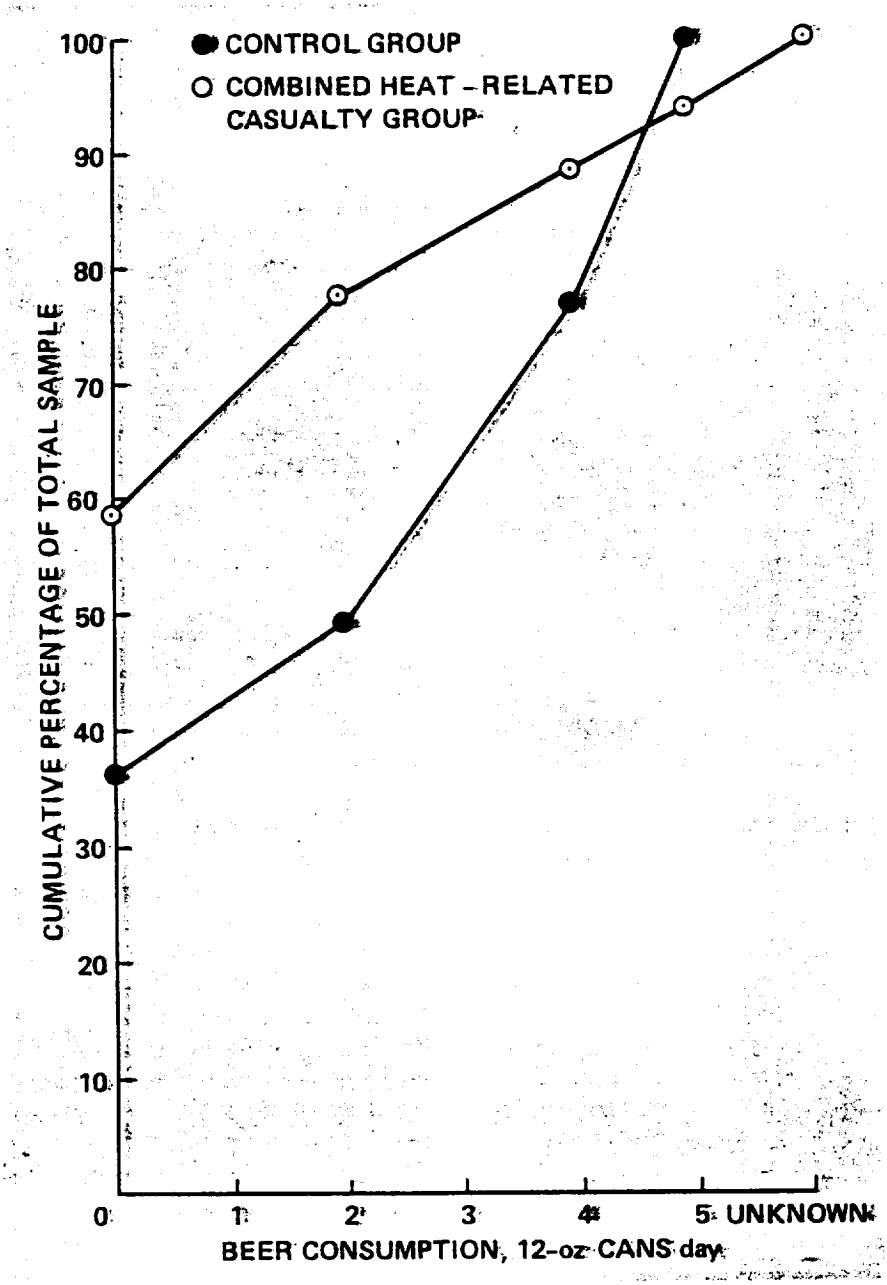

FIGURE 2. Average beer consumption by the control and HRC groups.

TABLE 9. Water Consumption (Percent of Total)

Canteens	Controls	HRC 1979	HRC 1982	Combined HRC 1979 & 1982
<2	13	15	12	14
3-5	51	69	65	68
6-8	26	12	17	13
>9	10	4	6	5
Unknown	0	0	0	0

TABLE 10. Water Consumption Patterns (Percent of Total)

Drank on Schedule	Controls	HRC 1979	HRC 1982
Yes	41	No	47
No	59	Data	53
Unknown	0		0
Drank When Thirsty			
Yes	46	No	71
No	52	Data	29
Unknown	2		0

meals. Thirty-six percent of the control group members had six or more canteens of water, whereas only 18 percent of the combined HRC's consumed that much water. On the lower end of water intake, the percentages for the controls and the combined HRC group who consumed less than five canteens of water were 64 percent and 82 percent, respectively. Thus, the HRC group appeared to consumed somewhat more salt and less water than the control group.

It seems that the HRC group was drinking on a schedule, much like the control group. Table 10 lists the results concerning the method of drinking: drinking on a schedule and drinking only when thirsty. There does not appear to be any significant difference in the two groups concerning schedule drinking, but when asked if they drank only when thirsty, the difference becomes more noticeable. Seventy-one percent of the HRC group drank only when thirsty; only 46 percent of the control group drank only when thirsty. Again, the HRC group was probably not drinking enough water.

Another interesting point gained from the interviews with the HRC group concerned the level and type of activity they were engaged in before becoming a casualty. In 1979 63 percent of the heat casualties were riding in, or had been riding in, a vehicle (helicopter, jeep, amtrak, tank) at least 1 hour before becoming ill. In 1982 the percentage was only 42 percent. As a followup of the 1978 observations, a study sponsored by the Office of Naval Research was conducted at Ames Research Center to determine if vibration reduced tolerance to hot environments. Results suggest that the low-frequency (5-16 Hz), whole-body vibrations reduced tolerance during heat exposures with the effects lasting for at least 1 hour after cessation of the vibration.(*11*) These frequencies are commonly generated by the various personnel carriers used in the desert.

It should also be noted that radio operators and personnel who lay wire tended to be higher heat casualty risks. In the 1978 HRC group there were large numbers of heat casualties associated with cooking and cleaning in the galley, while in the 1982 HRC group no casualties were associated with food preparation services. The difference in casualty rate between these two galley crews was possibly due to the construction of a permanent food service structure after 1979 and to lower temperatures during the 1982 exercise.

There is always the possibility that an HRC may provide the expected answer when questioned and may not be providing the truthful answer; however, most of the information sought cannot be categorized into right or wrong answers. Assuming most of these answers were truthful, then some factors can be reported which were found to be associated with the HRC group. Again, a cause-and-effect relationship has not been shown in this study, only an association. The following points should be emphasized.

- Exercise or inappropriate working levels above environmental heat-stress condition II resulted in more HRC's.
- People from warmer sections of the country may be at greater risk of heat-related illnesses since many live and work in air-conditioned homes and offices and may not attain a sufficient level of natural heat acclimatization.
- The importance of sleep should be emphasized more, with at least 6 hours being the recommended minimum.
- Women did not appear to be at greater risk than men.
- Consumption of fewer than five 12-oz cans of beer at night was not associated with a reduced tolerance to the heat and may actually be beneficial as a fluid replacement mechanism; more data are needed.
- The heat-related casualty group seemed to be drinking insufficient fluids. The onset of thirst is not a good indicator of the level of dehydration because exposure to heat, exercise, and dehydration masks the feelings of appropriate thirst.(*3*) Troops must be forced to drink before thirst becomes apparent or progressive dehydration will result, particularly when working or marching.

Treating Heat Casualties in the Field. Spray-misting a seminude heat casualty on a net hammock is a more efficient procedure for removing body heat(*13*) than immersing in ice water or covering the patient with ice water-soaked sheets.(*1,4,12*) Spray-misting applies a film of water onto the skin that allows for evaporative cooling, the most efficient means of heat dissipation, especially if a fan blows air across the patient. The net hammock allows evaporation to occur from the back of the patient as well. Skin cool-

ing is maximized with spray-misting.

Immersion of the patient in ice water relies on conductive-convective cooling (a less efficient method than evaporation) that requires heat to be transported from the muscles and organs to the skin via the blood where heat is transferred from the warmer blood to the ice water cooled skin. However, excessive cooling of the skin will virtually abolish peripheral blood flow, and heat transfer will be severely curtailed. As a result, core temperature may even increase because heat production exceeds heat dissipation. Also, in the field, the standing ice water bath procedure is not as practical as spray-misting. The spray-mist water need not be cooled; it can be warm but should not be allowed to become hot. Evaporation of 1 ml of warm water removes essentially the same amount of heat as evaporation of 1 ml of cold water.

In all but extremes cases, localized spraying of the body may be better than whole body spraying. Localized spraying tends to reduce shivering, which increases heat production, and to reduce the degree and duration of vasoconstriction in the skin. Spray-cooling should be started in the field by the unit corpsmen. The head and neck area, chest and back, arms and hands, and legs and feet are four localized areas that should be sprayed as units.

Hand-pump sprayers, which are commonly sold for home insecticide use (2- to 3-gal capacity), can be issued to each battalion aid station and to the field hospital. One-quart hand sprayers, which are used to mist house plants, work well for the corpsmen, are cheap, and can be filled from a canteen. In 1982 15 one-quart sprayers were given to hospital corpsmen with the marines on the range during the live-firing exercises. All corpsmen spoke highly of the efficiency of the sprayers in the field and reported that after patients were cooled and allowed several hours of rest with oral rehydration, many of the potential casualties were returned to their units without further treatment. Many heat casualties would normally have been sent to the battalion aid station or to the field hospital at Camp Wilson.

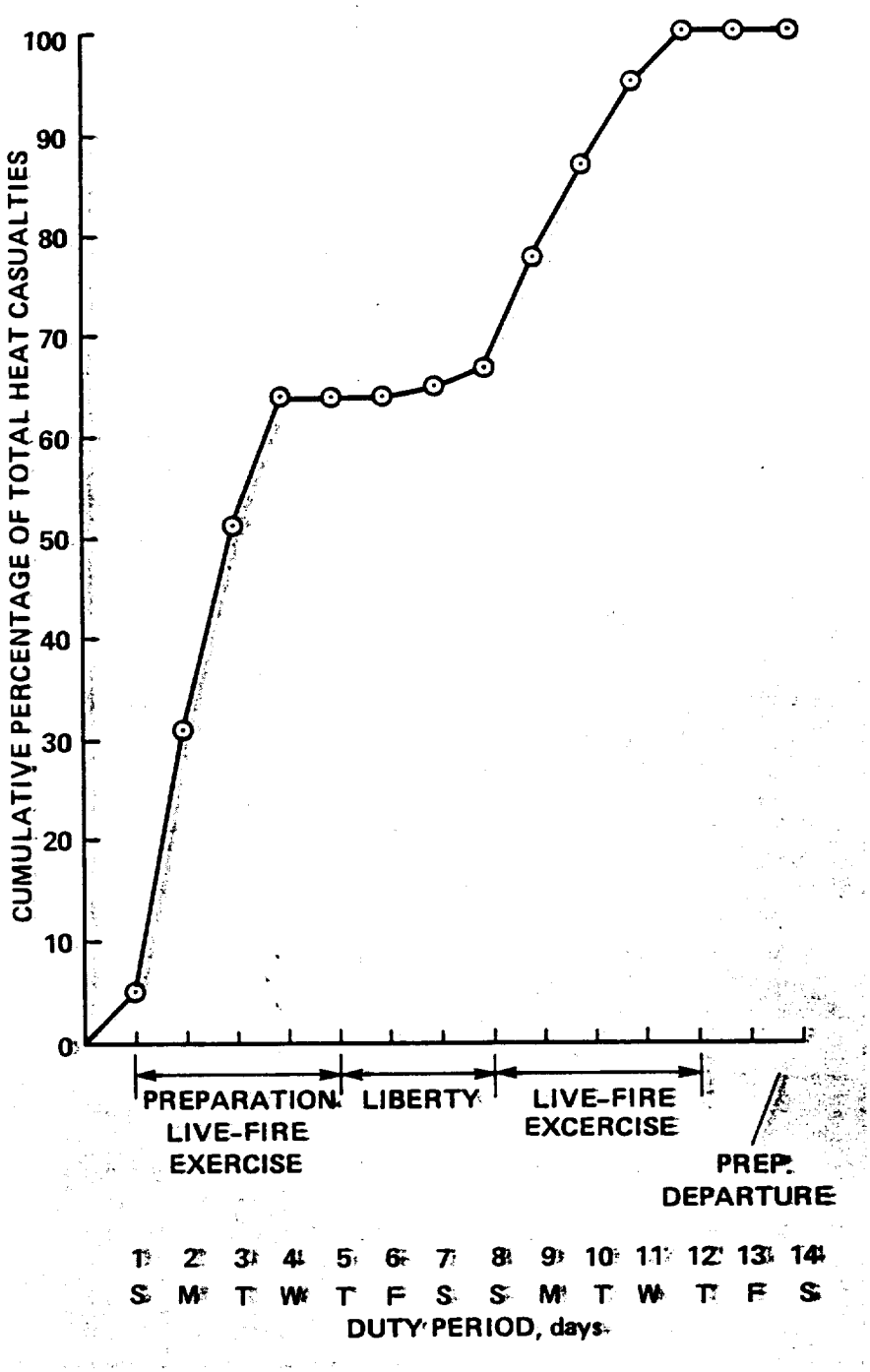

FIGURE 3. Cumulative percentage of total HRC's during the 14-day exercise period.

The field hospital and battalion aid stations should be equipped with battery-operated thermistor instruments for taking body temperatures. Currently, the aid stations and field hospitals are using mercury thermometers which must be kept cool in water or on ice. It is very difficult to obtain accurate body temperatures with these thermometers because the mercury starts climbing when the ther-

TABLE 11. Symptoms in HRC's (Percent of Total)

Symptoms	HRC 1979	HRC 1982	Combined HRC 1979 & 1982
Cramps	36	6	33
Nausea	51	41	50
Vomiting	20	23	20
Vertigo, Dizziness	52	41	50
Hot, sweating	26	29	26
Hot, dry	10	3	9
Headache	23	21	23
Cold, clammy	10	12	10
Unconscious	2	0	1

mometer is removed from the patient. Also, free mercury is hazardous.

Among the various Reserve medical units assigned to staff the field hospitals, there appears to be a propensity for using intravenous solutions on every HRC. Since the vast majority of HRC's (99 percent in these two exercise periods) were conscious, there are few good reasons to use intravenous solutions to rehydrate every patient when oral intake is considerably cheaper and safer. The exception is frank heat stroke with coma. Many of the nauseated and vomiting HRC's were able to take fluids orally after a brief period of spray cooling.

Field hospital personnel should plan to treat HRC's as their primary case load before arriving in the desert. As seen in Figure 3, almost two-thirds of the total HRC load occurred within the first 4 days, particularly during the June and July exercises. The last third of the total heat casualty load occurred during the 3 or 4 days of war-training exercise during the second week. Signs and symptoms reported as a percentage of the HRC are listed in Table 11.

Heat-stroke victims should be cooled rapidly, especially by the corpsmen in the field. The patient should then be evacuated to the branch hospital at Twentynine Palms Marine Base or to Camp Pendleton, depending on the branch hospital capabilities at the time. These plans should be organized early before each CAX period by the field hospital staff.

Recommendations for Equipment and Procedural Modifications

- Flax water bags should be more readily available and should be issued to troops in the deserts, since the warm water in the canteen usually becomes unpalatable. A more durable flax bag should be designed, one that could be attached to the pack or carried elsewhere out of the way. Warm water can then be transferred from canteens to the flax bags for cooling.
- At Camp Wilson's mess hall, most of the troops reported drinking about two to three small paper cups of fluid during meals. A larger cup, about pint size, may be an easy way to get the troops to consume larger quantities of fluids. Extra rations of fluids at meals should be encouraged and made readily available. The additional cost involved in the use of extra packaged fluid mixes is minor by comparison with the cost of one round-trip medical helicopter trip to Camp Pendleton or hospitalization of a few casualties.
- The black plastic 5-gal water containers, which carry the water for the tank crews and other groups, should be painted a lighter color to increase reflectivity, thereby keeping the water cooler.
- Since most tanks are not air-conditioned, interiors become very hot in a short time. The feasibility of installing small fans (particularly for the gunner and driver) should be considered. If the fans were directed toward the heads of the crewmembers, the likelihood of heat stress would be reduced and sweat would be kept out of their eyes. Additionally, there is a psychological effect of head cooling which reduces the error rate of mental calculations caused by overheating.(*7*) NASA has developed very small portable cooling units that can be connected to a conductive cooling vest (*10*) and cap.(*5,7*) These can be worn under the flak vests and helmets of tank crews. Such units could also be used to cool drinking liquids. With these additions, the tank crews could stay "buttoned up" much longer with respect to heat tolerance limits.
- The non-air-conditioned ambulances used in the field should be fitted with air scoops or windows that could be opened to cool the back area where the patients are carried. Small, oscillating recreational vehicle fans would also be useful in the patient area.
- Since most of the heat casualties occurred during noncombat tasks, such as cleaning details around the base camp, running wire, loading and unloading trucks and tanks, and setting up the base camp, serious consideration should be given to the design of uniforms. A military tropical/desert style of shorts could be worn during these tasks. The current green uniform is poorly designed for evaporative heat exchange and probably contributes significantly to the high rates of heat casualties that occur. British and Israeli troops, both of whom have engaged in considerable warfare in hot climates, have used tropical shorts for years.

• A personal desert handbook for each marine should be prepared and issued which provides information on drinking by a schedule, early warning symptoms and treatment of heat exhaustion and dehydration, work/rest cycles for maximum performance, both identification of poisonous snakes and arthropods, and first aid to be used if bitten. Other safety procedures, such as reporting unexploded ordnance, should also be included.

The loss of manpower through heat casualties is evident. However, attention should also be directed toward stemming the degradation of both physical(*2,4,9*) and mental(*6,8*) performance caused by exposure to heat and other stresses of desert exercises. In conclusion, results from these two field studies indicate that heat-related casualties were neither getting sufficient sleep nor drinking enough fluids—factors that reduce tolerance and performance during prolonged exposure to hot environments.

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In Memoriam

CAPT *Lamar R. Smith,* MSC, and his wife Yvonne died in an aircraft accident on 25 Feb 1984 in Princeton, WV.

Born in Stockdale, TX, on 18 July 1930, CAPT Smith received his B.S. degree in pharmaceutical science from the University of Texas in 1957 and an M.A. from the University of Arizona in 1971. He joined the Navy in 1951 and served in Korea with the Marine Landing Force. In 1964 CAPT Smith completed Officer Candidate School and served in Vietnam from 1967 to 1968.

CAPT Smith was a member of the American Society of Hospital Pharmacists, and in 1970 was admitted to the World Apothecary Association at the meeting in Canada. He was director of naval hospital pharmacies in Europe while stationed in Italy in 1974. In 1978 he was director of the Navy Pharmacy School in Portsmouth, VA, and in 1980 was the chief pharmacist stationed at the National Naval Medical Center, Bethesda, MD. His last assignment was at the Defense Personnel Support Center in Philadelphia as director of technical operations for the medical directorate.

CAPT Smith's decorations included the Presidential Unit Citation, the Navy Unit Commendation, the Meritorious Unit Commendation, Korea and Vietnam Service and Campaign Medals, and the Good Conduct Medal. In 1983 he received the

Meritorious Service Award. CAPT Smith was also voted Preceptor for the Howard College of Pharmacy.

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